

**APPLICATION
FOR
UNITED STATES LETTERS PATENT**

APPLICANT NAME: Edward W. Conrad and David P. Paul

TITLE: Method and System For Measurement of Full Two-Dimensional Submicron Shapes

DOCKET NO. BU9-99-152

INTERNATIONAL BUSINESS MACHINES CORPORATION

CERTIFICATE OF MAILING UNDER 37 CFR 1.10

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METHOD AND SYSTEM FOR MEASUREMENT OF FULL
TWO-DIMENSIONAL SUBMICRON SHAPES

Background Of The Invention

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This invention generally relates to measuring submicron structures or shapes; and more specifically, the invention relates to measuring such shapes from electron beam images of the shapes. Even more specifically, the present invention relates to a measurement procedure and system particularly well suited for determining the relative position of edges of submicron structures or shapes formed by photolithography on semiconductor wafers.

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As photolithography K factors continue to decrease and complex reticle enhancement techniques are employed, the printed shapes appearing on the wafer can vary dramatically from the design in both shape and location.

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The traditional metrics of line width and overlay, although still useful, often are inadequate for predicting many effects on product. A means of accurately measuring wafer images in a full two dimensions is required for a variety of applications including fully understanding effects of imaging, etching, and other wafer processing on product performance. Another especially important application of two-dimensional shape metrology is for use in the calibration of shape prediction models that are just becoming widely offered in the semiconductor industry.

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5 Little has been done in the area of full two-dimensional
submicron shape metrology. Early two dimensional
submicron measurements are generally achieved with a top
down SEM. Metrology SEMs are generally one-dimensional
instruments, that scan in a single direction that is
approximately normal to the edge to be detected. An edge
detection algorithm is then applied to this signal.
Early attempts at two-dimensional metrology with SEM's
consist of multiple one-dimensional measurements (e.g. to
10 evaluate a bar, a scan along the width will be followed
by a different scan along the length). This treatment of
shapes is generally inadequate for many applications in
terms of quantity of data and it is customary for the
scans to be independent (i.e. the two scans are not
15 connected by a coordinate system with a single origin).

Summary Of The Invention

20 An object of this invention is to improve methods and
systems for measuring submicron shapes.

Another object of the present invention is to use an
image of a submicron shape to identify relative position
25 of edges of that shape.

These and other objectives are attained with a method and
apparatus for extracting two-dimensional image shapes
from image data on a pixel array. The method comprises
30 the steps of selecting intensity vs. pixel information in
at least one direction in the vicinity of an edge of the
image shape, and recognizing scans with sufficient

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contrast as containing edge information. Acceptable scans are subjected to an edge detection algorithm and the edge location is detected. The locus of points generated from applying edge detection at multiple points around the image define the two-dimensional shape of the image.

Any suitable edge detection algorithm may be used. That algorithm may be a user defined edge detection algorithm tailored for the application, and, for example, a threshold edge detection algorithm may be employed. Also, in a preferred embodiment, the selecting step includes the step of selecting intensity vs. pixel information in at least four directions, and the plurality of directions are angularly spaced apart at least about 45 degrees. With one embodiment, one of these directions may be normal to an approximate edge location.

Further benefits and advantages of the invention will become apparent from a consideration of the following detailed description, given with reference to the accompanying drawings, which specify and show preferred embodiments of the invention.

Brief Description Of The Drawings

Figure 1 shows an SEM micrograph of a resist "L" shaped structure.

Figure 2 shows the plot of a shape using constant contour intensity approximation.

Figure 3 shows the area of an "L" shape that was selected for scans.

5 Figure 4 is a graph of the intensity value vs. pixel location for the pixels along a forty-five degree scan.

Figure 5 is a graph of the intensity value vs. pixel location for the pixels along a horizontal scan.

10 Figures 6 and 7 show graphs of the intensity value vs. pixel location for the pixels along two additional scans suitable for edge detection.

15 Figure 8 shows the graphs of Figures 4-7 superimposed.

Figure 9 shows the measured shape resulting from a method embodying the present invention.

20 Figure 10 shows the shape of a structure determined by using a constant intensity method, and the shape of the same structure determined by using a method embodying this invention.

25 Figures 11 and 12 show enlarged portions of Figure 10.

Figures 13 and 14 show a computer system that may be used in the invention.

30 Figure 15 illustrates a memory medium that can be used to hold a computer program for carrying out this invention.

Detailed Description Of The Preferred Embodiments

The method being disclosed makes use of a two-dimensional SEM image which consists of a regular grid of detector
5 signal values that have a one-to-one correspondence with the position of the electron beam. The detector signal is related to the number of electrons collected by one or more detectors as a function of beam location on the sample under investigation.

10 Figure 1 shows a typical SEM micrograph. The images in Figure 1 comprise a set of "L" shapes which include corners such that edges are oriented at all angles from horizontal to vertical. Traditional SEM metrology of
15 such a sample would require multiple mountings of the sample in various rotation states, or multiple scans with a rotated beam. For high accuracy measurements, each of the beam rotation states requires a separate calibration.

20 The method disclosed herein makes use of the fact that the detector signal peaks in the vicinity of an edge, as shown in Figure 3. Since the edge is at a higher intensity than the rest of the background a relatively high constant intensity contour gives an approximate
25 estimate of the edge location, as shown in contour plot of Figure 2. Using this approximate edge location as a starting point, a line or scan of pixel intensities can be selected that passes through the approximate edge pixel location in any of many directions.

30 It is possible to make use of the normal to the approximate edge location and interpolation to produce

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intensity vs. position for lines that pass through the approximate edge at very close to normal. However, in practice it is found that by selecting intensity vs. pixel location for four directions, the edge can be reliably detected. Four scans ensures that a scan will be no more than 22.5 degrees off from the normal to the edge. More or less scans would also, generally, produce acceptable results.

Figures 4-8 show selected pixel intensity vs. pixel number for the x direction, the y direction, and each of the two +/-45-degree directions the designated (circled) area at the bottom of the shape in Figure 3. Three of the four scans show good "contrast" (or range of intensity variation) as the edge is crossed. The horizontal scan shows no significant change in intensity with pixel number since the scan is along the direction of the edge. By sorting the data based on this contrast, poor quality scans that will produce erroneous edge location values (especially those that run nearly parallel to and edge) can be detected and discarded from the data.

By applying this four-scan method to all pixels near the edge of the shape of interest, it is possible to produce a full two-dimensional image shape where each point on the edge shares a common origin. The result is shown in Figure 9. In particular, to obtain the result shown in Figure 9, four scans were applied at each of the constant intensity points until the entire shape was tested.

Figure 10 shows both the shape measured by using a constant intensity method and the shape measured by using a method embodying this invention. Figures 11 and 12 show enlarged portions of Figure 10. It should be noted that the method of this invention, in comparison with the constant intensity approximation method, produces a narrower vertical line width for the constant intensity value and edge detection algorithm used here.

Although the technique disclosed herein was developed for SEM metrology, it applies equally well to other detection devices, such as optical, AFM, and SFM.

The data processing needed to perform this invention may be done on any suitable computer, and Figure 13 illustrates, as an example, a computer of a type that may be used in the practice of this invention. Viewed externally in Figure 13, a computer system has a central processing unit 42 having disk drives 44A and 44B. Disk drive indications 44A and 44B are merely symbolic of a number of disk drives that might be accommodated by the computer system. Typically, these would include a floppy disk drive such as 44A, a hard disk drive (not shown externally) and a CD ROM drive indicated by slot 44B.

The number and type of drives vary, usually, with different computer configurations. The computer has the display 46 upon which information is displayed. A keyboard 50 and a mouse 52 are normally also available as input devices.

Figure 14 shows a block diagram of the internal hardware of the computer of Figure 13. A bus 54 serves as the

main information highway, interconnecting the other components of the computer. CPU 56 is the central processing unit of the system, performing calculations and logic operations required to execute programs. Read only memory 60 and random access memory 62 constitute the main memory of the computer. Disk controller 64 interfaces one or more disk drives to the system bus 54. These disk drives may be floppy disk drives, such as 66, internal or external hard drives, such as 70, or CD ROM or DVD (Digital Video Disks) drives, such as 72. A display interface 74 interfaces a display 76 and permits information from the bus to be viewed on the display. Communications with external devices can occur over communications port 78.

Figure 15 shows a memory medium 80 that may be used to hold a computer program for implementing the present invention, and this medium may be used in any suitable way with any appropriate computer to carry out the invention. Typically, memory media such as a floppy disk, or a CD ROM, or a Digital Video Disk will contain the program information for controlling the computer to enable the computer to perform its functions in accordance with the invention.

While it is apparent that the invention herein disclosed is well calculated to fulfill the objects stated above, it will be appreciated that numerous modifications and embodiments may be devised by those skilled in the art, and it is intended that the appended claims cover all such modifications and embodiments as fall within the true spirit and scope of the present invention.